AN ALLUVIAL FAN AT APOLLINARIS PATERA, MARS. R. C. Ghail and J. E. Hutchison, Department of Earth Science and Engineering, Imperial College London, Royal School of Mines, Prince Consort Road, London, SW7 2BP, United Kingdom. [1]*R.Ghail@imperial.ac.uk,* [2]*Jemima.Hutchison@imperial.ac.uk*

Introduction: Apollinaris Patera, Mars (7˚S, 173˚E), is an intermediate sized volcano (~6 km high, 150 km diameter) with a large (200-km long) fan-like deposit on its southern flank. This fan is deeply incised and originates from a single breach in the rim of the summit caldera. New topographic and multispectral image data reveal that this fan is alluvial, implying a long-lived source of (volcaniclastic) sediment and water (probably from a caldera lake).

Modes of Origin: Robinson [1], working from Viking data, noted a scarcity of narrow valleys on the fan that are observed elsewhere on the flanks of Apollinaris (and inferred by him to imply a flank composition of unconsolidated pyroclastic material) on the fan, implying that it is composed of more competent material. The lack of high-relief flow lobes argues against high-effusion rate a'a-type flows. He therefore proposed that the fan is composed of pahoehoe-type lava flows erupted at a low effusion rate, which have flow lobes invisible at Viking resolution. New data, particularly high-resolution (~5 m) MOC imagery, have failed to reveal the predicted pahoehoe-type flows on the fan and instead reveal two different types of ridges seperated by V-shaped valleys apparently infilled with loose sedimentary material that occasionally exhibits dune formation.

A series of pyroclastic flows might have produced the fan; the competency problem suggested by Robinson can be addressed by welding of the flows while still hot. However, the origin of the fan at a single breach in the caldera rim presents a problem: it is highly unlikely that multiple pyroclastic flows would have the same local point of origin on so large a volcano. The incised V-shaped valleys on the fan are also not consistent with aa series of pyroclastic flows and must, at the least, imply later modification of the fan.

Debris flows can also be rejected on the basis of scale and morphology. The volume of the fan (approximately 60 000 km^3) is approximately three times that of the potentially "missing" volume calculated by extrapolating the flank slopes of Apollinaris up from the caldera. Even assuming a high porosity for the fan, it is very unlikely that all this material was removed at a single point on the flanks to build up the observed fan. Furthermore, the slope of the fan (less than 2˚) and of the upwardly-concave incised valleys are inconsistent with the slopes and morphology generated by debris flows.

The only remaining interpretation, consistent with the observations, is that of an unconstrained alluvial fan. The point-source at the caldera-rim breach, low-angle slope of the fan, the V-shaped cross-sections and upwardly-concave along-length profile of the valley-floors are all consistent with an alluvial fan mode of origin. Nonetheless, its volume is unusually large, probably the largest in the solar system, implying a long-lived source of both water and sediment. Alluvial fans are most often associated with active normal-fault mountain fronts (*e.g.*, Star Valley, United States), although they can form at growing thrust faults (*e.g.*, Flaming Mountains, China). Catchment areas above the developing mountain front are usually captured at a few 'nick-points' along the mountain front, and from there flow out onto a growing sub-aerial delta; the alluvial fan. Usually, alluvial growth is constrained laterally by neighbouring fans, which combine into an advancing distal fan-front. The fan at Apollinaris has, unusually, developed in isolation, indicating a single source of both sediment and water that escaped through a single nick-point, the calera-rim breach.

Emplacement Hypothesis: The obvious source of water for an alluvial fan was a caldera lake which existed in the main caldera following its formation but prior to the final caldera collapse that formed the youngest caldera in the northern half of the summit (Fig 1). We suggest that at this time a small volcano existed more-or-less at the location of the youngest caldera, surrounded by a lake in the main caldera that, on the basis of modern MOLA topography, was several hundred metres deep and had a surface (which may have been frozen) at the same elevation as the caldera-rim breach. Summit winter snowfall kept the lake supplied with water and a relatively small volume of sediment, most of which was deposited on the lake floor. Water drained through the breach and dispersed out along the V-shaped valleys observed on the fan. Intermittent pyroclastic eruptions from the small volcano at the north end of the caldera sent pumice, ash and lake water cascading through the breach and onto the fan, building up the alluvial deposits. This process must have continued for millenia (an exact timescale is impossible to quantify at this stage) but was eventually terminated by a caldera collapse of the volcano in the northern part of the main caldera. This caldera collapse removed part of the northern rim to a level lower than that of the main lake. Evidence for the rapid drainage of the main caldera lake is found in the deeply incised channels (Fig 3) on the northern

APOLLINARIS ALLUVIAL FAN. R. C. Ghail & J. E. Hutchison, Dept Earth Sci. & Eng., Imperial, London, SW7 2BP, U. K.

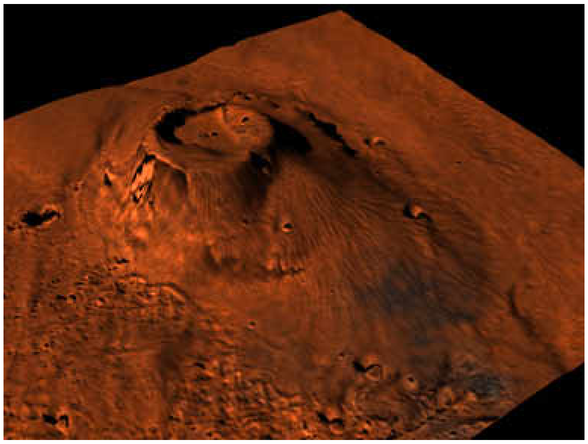

Fig 1. Perspective view across Apollinaris Patera and its southern fan; Viking imagery on MOLA topography

flanks of Apollinaris. Although there is some evidence for a small lake remaining in the new caldera in the northern half of the summit, it was at a level well below the rim breach and so could not have supplied material to the alluvial fan, the growth of which must have ceased at that time.

Implications: The age of Apollinaris and its fan material is poorly constrained at present, ranging from Hesperian to lowest Amazonian, or between 925 Ma and 3·5 Ga [2, 3]. The climate at that time is also not well known; Ma'adim Vallis, less than 500 km southeast of Apollinaris, is approximately the same age. It was apparently supplied by rain or snowfall at its southern end, and flowed directly through an arid environment (much like the modern Nile River). There is little evidence for continual fluvial activity lower down on the flanks of Apollinaris but this does not preclude the accumulation of snow on its summit. The formation of a caldera lake, even with a frozen surface, at an elevation of approximately 5·5 km, has important implications for martian climatology. Atmospheric pressure at that altitude must have been at least 610 Pa, implying a pressure of at least 1200 Pa in the northern plains, sufficient to support large bodies of water there. Given the probability of snowfall on the summit of Apollinaris, it is likely that the atmospheric pressure was perhaps half as much again, so that the surface pressure was two to three times its present value.

The alluvial fan at Apollinaris gives an insight into a period of time when the planet was dying – but not yet dead – during which even intermittent volcanic activity maintained a hydrologically active climate.

References: [1] Robinson, M. S., *et al*. (1993) *Icarus, 104,* 301-323. [2] Neukum, G., & Wise, D. U. (1976), *Science, 194,* 1381-1387. [3] Soderblom, L. A., *et al.* (1974), *Icarus, 22,* 239-263.

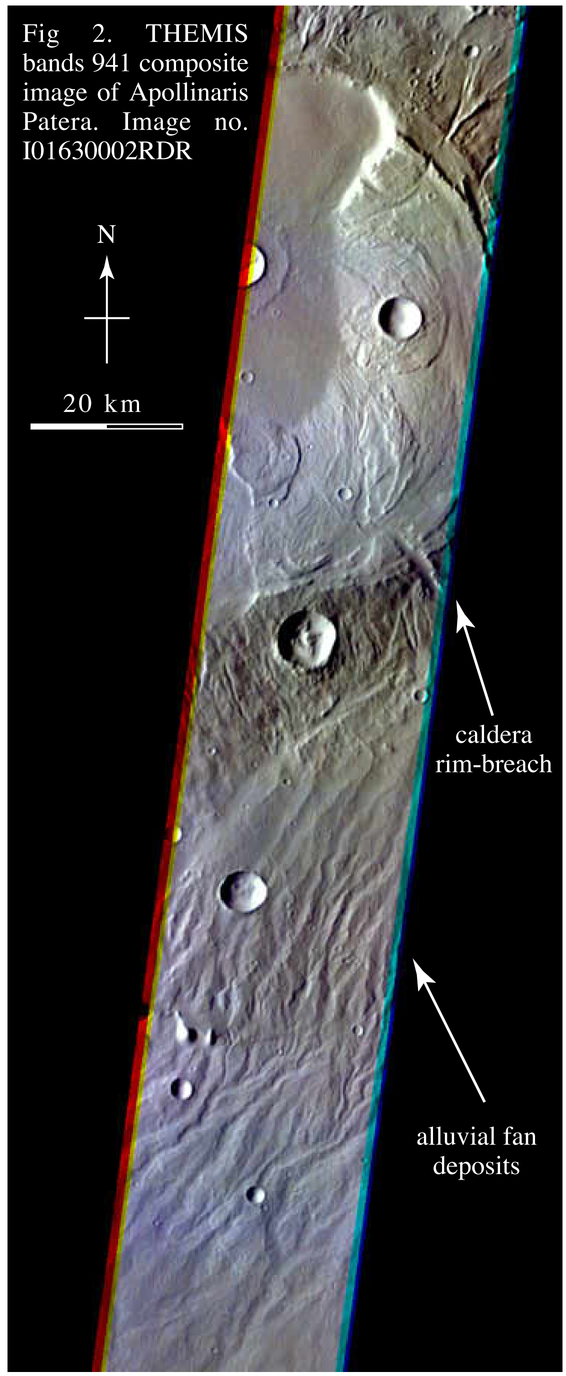

Fig 2. THEMIS bands 941 composite image of Apollinaris Patera. Image no. I01630002RDR